

ACM SIGGRAPH 94
21st International Conference
on Computer Graphics
and Interactive Techniques

Fundamentals Seminar

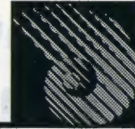


Conference
24-29 July 1994

Exhibition
26-28 July 1994

Orange County Convention Center
Orlando, Florida

SIGGRAPH '94 Fundamentals Seminar



Quotes

In the Exhibition

"... RISC implementation gives parallel access to a hi-res 4x4 interleaved 32 bit framebuffer with extra channels for alpha and z-depth, and real time quad buffering of fully textured, Gouraud shaded, reflectance mapped, ray-traced NURB surfaces with full antialiasing, while conforming to both PEX and OpenGL standards for use in an immersive VR environment with HDTV potential..."

SIGGRAPH '94 Fundamentals Seminar



Quotes

In the Panel Sessions, Courses & Papers

"... the volume visualization was done by considering all of the voxels with a marching cubes approach to the isosurface, while emdedding the gamut of the printer in CIELAB space so as to maintain ideal saturation so the JPEG compression can fractalize the signal with a genetic algorithm using a codec based on hierarchical wavelets and ... "

SIGGRAPH '94 Fundamentals Seminar



Our goal today:

- Present the *fundamentals* of computer graphics hardware, software, and application areas in a straightforward manner, with as little of this technical jargon as possible.

SIGGRAPH '94 Fundamentals Seminar



Speakers

Wayne E. Carlson

The Ohio State University

**Advanced Computing Center for the
Arts and Design (ACCAD)**

Michael J. Bailey

San Diego Supercomputer Center

Judith R. Brown

University of Iowa

Weeg Computing Center

SIGGRAPH '94 Fundamentals Seminar



Special Thanks to:

- **SIGGRAPH '94 Conference Personnel**
Dino Schweitzer, Conference Chair
Mike Bailey, Courses Chair
Leigh Morgan
- **SIGGRAPH SVR and Slide Collections**
- **Other slide contributors**

SIGGRAPH '94 Fundamentals Seminar



Graphics Systems (Software)

- Wayne Carlson

Graphics Systems (Hardware)

- Mike Bailey

Applications, etc.

- Judy Brown

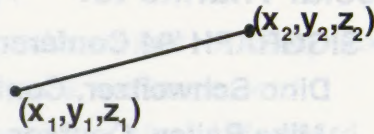
Primitives



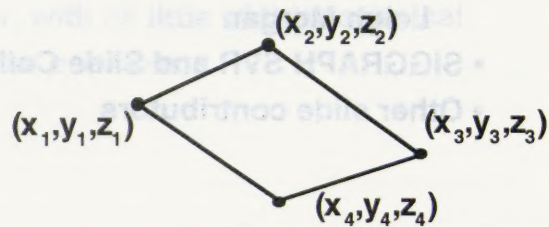
- Point

• (x_1, y_1, z_1)

- Line



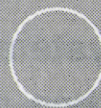
- Polygon



Primitives



- Circle /Arc



- Curve

polynomial, Bezier, b-spline, NURB, ...



Primitives



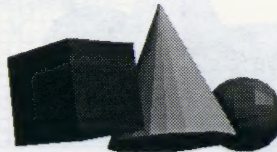
- Patch

Coons, Bezier, b-spline, NURB, ...



- Solid

cube, cylinder, cone, sphere, ...



Primitives



- Text

- outline
(eg, PostScript)



- bit-mapped

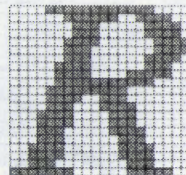
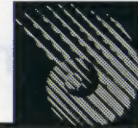


Image Dimensions

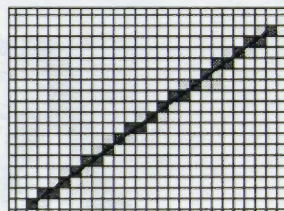


Scan Conversion



- Lines

- For each column or row in the frame buffer, color the pixel whose center is nearest the true line

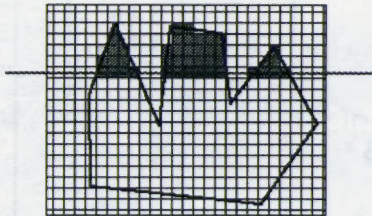


Scan Conversion



- **Polygons**

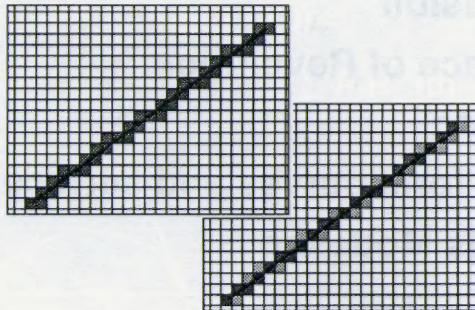
- For each pixel in the scan line, color it if its center is inside the polygon



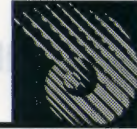
Scan Conversion



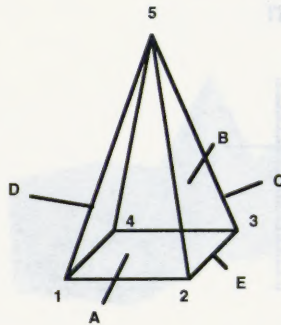
- **Antialiasing**



Modeling



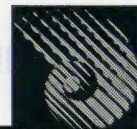
• Polygon Data Structure



Face List	
Face	Vertices
A	1 2 5
B	2 3 5
C	3 4 5
D	1 4 5
E	1 2 3 4

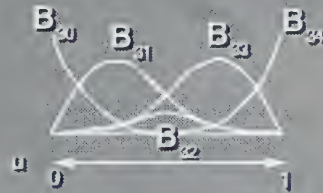
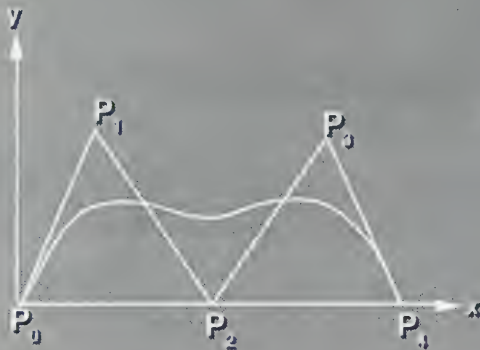
Vertex List	
Vertex	x,y,z
1	0,0,0
2	2,0,0
3	2,0,2
4	0,0,2
5	1,3,1

Modeling - Techniques



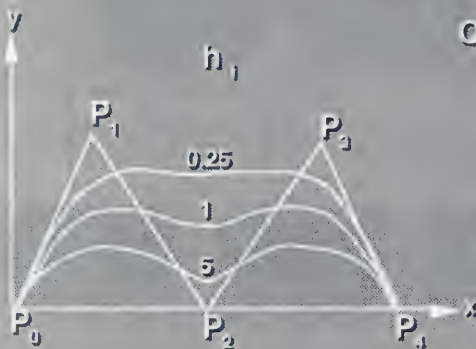
- Extrusion
- Surface of Revolution
- Lofting
- Free-form curves and surfaces
- Solids Modeling

Free-form curves



$$Q(u) = \sum_{i=0}^3 P_i B_i(u)$$

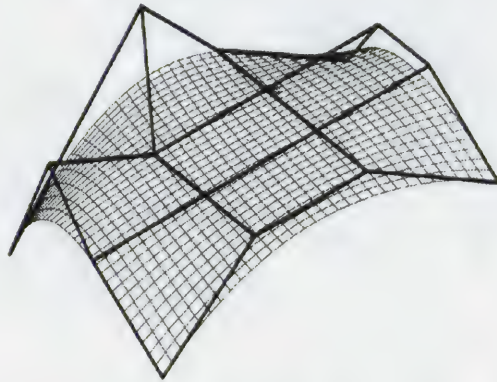
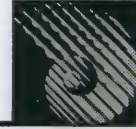
Free-form curves - NURBS



$$Q(u) = \sum_{i=0}^3 P_i R_i(u)$$

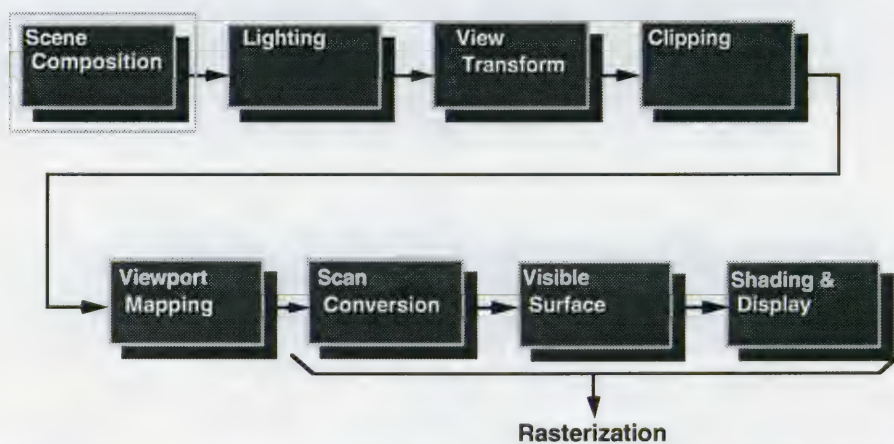
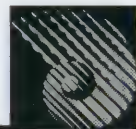
$$R_i(u) = \frac{h_i B_i(u)}{\sum_{i=0}^3 h_i B_i(u)}$$

Free-form surfaces

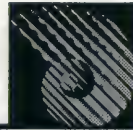


$$Q(u,w) = \sum_{i=0}^3 \sum_{j=0}^3 P_{ij} B_{3i}(u) B_{3j}(w)$$

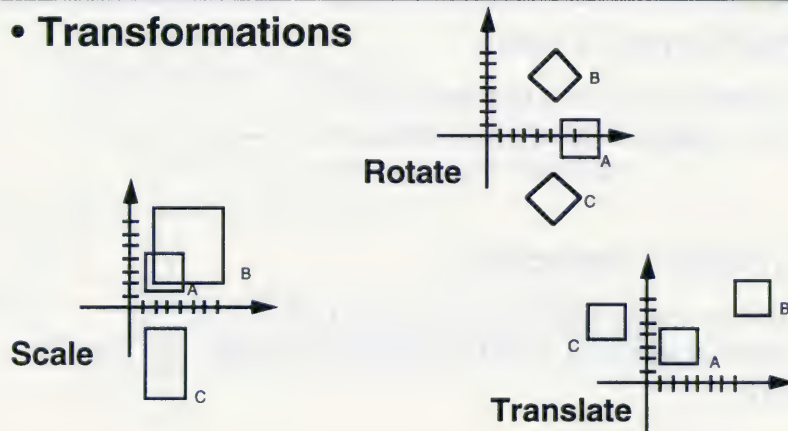
Making the Picture



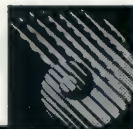
Scene Composition



• Transformations



Scene Composition



• Transformation Matrices

$$\begin{bmatrix} s1 & 0 & 0 \\ 0 & s2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Scale

$$\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Rotate

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t1 & t2 & 1 \end{bmatrix}$$

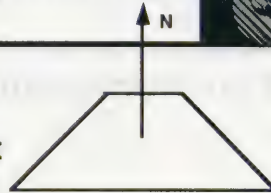
Translate

$$(x' \ y' \ 1) = (x \ y \ 1) M$$

Trivial rejection

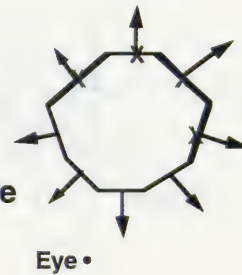
- **The Normal Vector**

Perpendicular to the polygon, it provides a sense of orientation

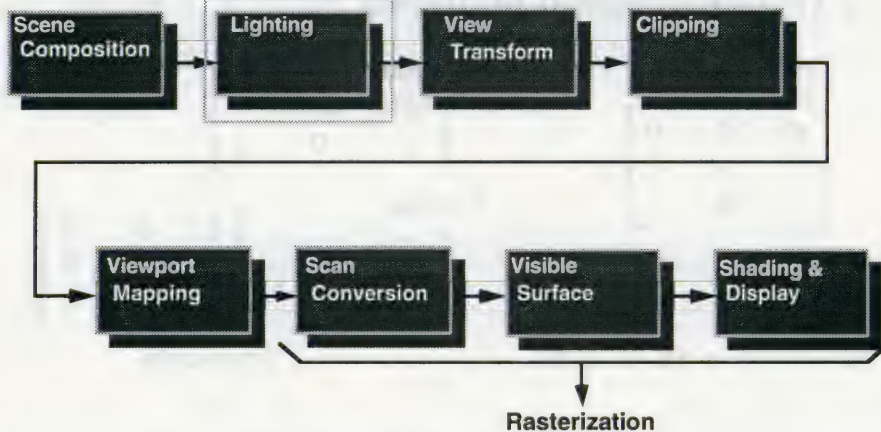


- **Backface Rejection**

Throw away all polygons that have normal vectors pointing away from the eye



Making the Picture



Lighting



- **Sources of lights**

- Ambient - some light at a point on the surface comes from light reflected from other surfaces
- Point light source - some light at a point on the surface comes directly from the source

Lighting



- **Surface attributes**

- Diffuse surfaces - light is absorbed and reemitted uniformly in all directions
- Specular surfaces - light is reflected directly from the surface at the same angle as it arrives

Lighting



- **Other influences**

- Light attenuation - the strength of the light is reduced as a function of its distance
- Atmospheric attenuation - some light is absorbed by elements of the atmosphere
- Light intensity and color
- Other types of light sources
eg, distributed

Lighting



- **Lighting Models**

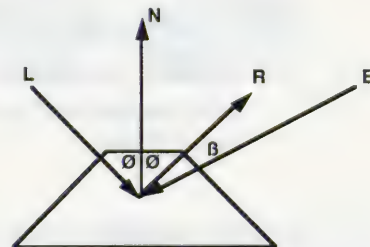
- Lambert model

$$I = k_a + k_d * \cos \theta$$

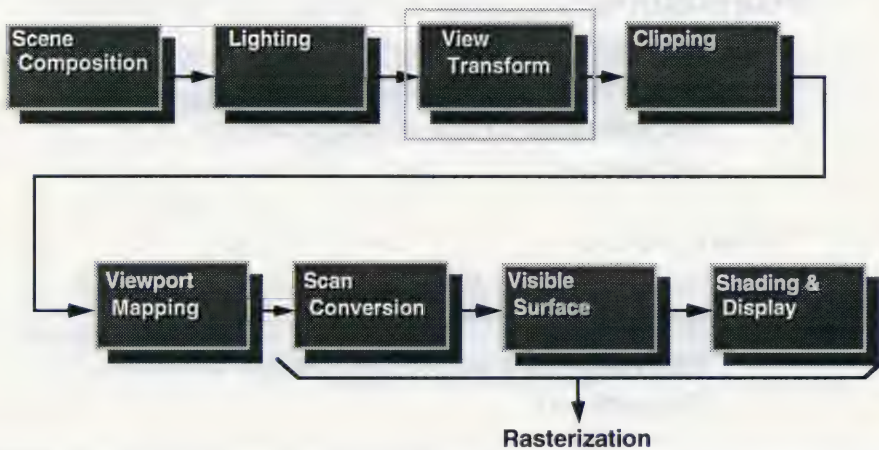
- Specular Reflection

- Phong Model

$$I = k_a + k_d * \cos \theta + k_s * (\cos \beta)^n$$



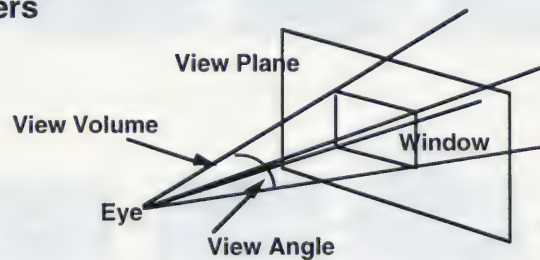
Making the Picture



View Transform

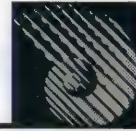


- Transform data from world coordinates into the space defined by the view parameters



- Project onto the view plane

View Transform



- **Projections**

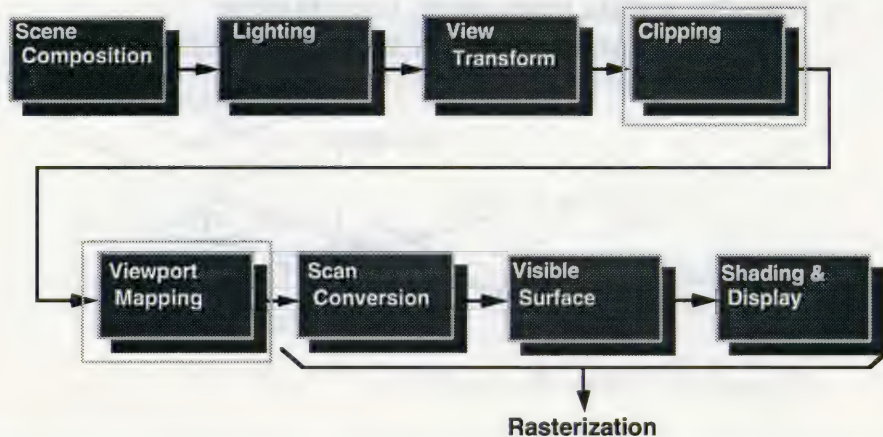
- **Orthographic (Parallel)**

The projectors through the coordinates of the objects never converge

- **Perspective**

The projectors through the coordinates of the objects converge at a point (the Center of Projection)

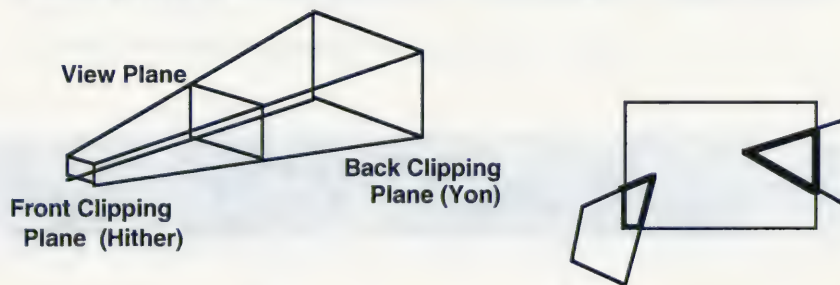
Making the Picture



Clipping



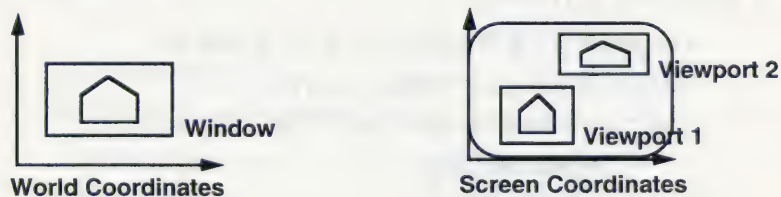
- Remove all parts of any primitive that are outside the boundaries of the view volume



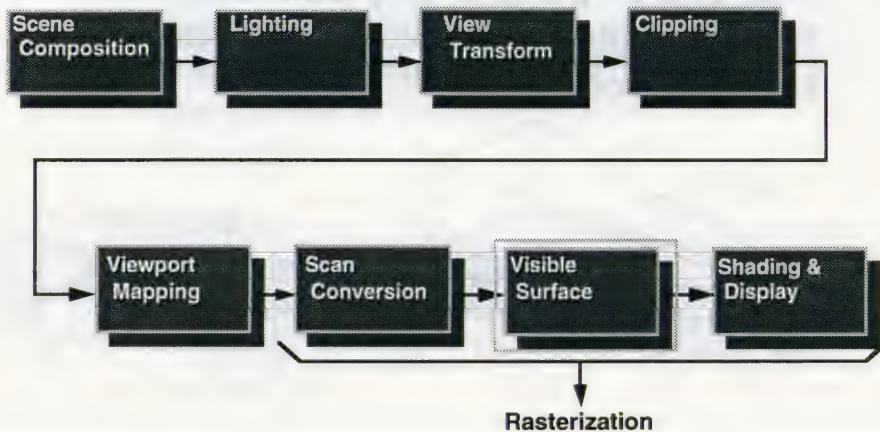
Viewport Mapping



- Transform the projected image from the window in the view plane to the viewport in which it will be displayed



Making the Picture

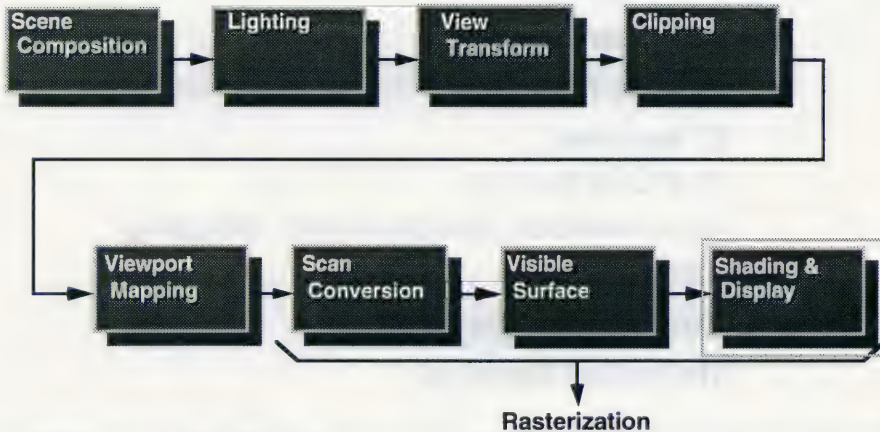
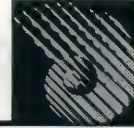


Rasterization



- **Hidden Line**
 - Remove all lines or parts of lines that wouldn't be seen if the objects were solid
- **Visible Surface**
 - Display only those faces or parts of faces that are visible by virtue of being closer to the eye than others
 - depth sorting
 - z - buffer

Making the Picture



Shading



- **Lighting Models**

- **Faceted (Flat shading)**

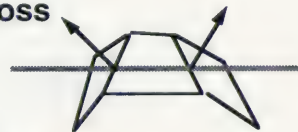
All intensities are the same across the polygon.

- **Gouraud smooth shading**

Intensities across the polygon are interpolated

- **Phong smooth shading**

Intensities across the polygon are calculated from interpolated normal vectors



Shading



- **Surface Effects**
 - **Transparency**
 - **Texture Mapping**
 - 2D textures
 - 3D (Solid) textures
 - Bump Mapping (Displacement Mapping)
 - **Shadows**
 - **Environment Mapping**
 - (Reflection Mapping)

SIGGRAPH '94 Fundamentals Seminar

**Fundamentals of Hardware
for Computer Graphics**

© 1994 Mike Bailey

SIGGRAPH '94 Fundamentals Seminar

**Dr. Mike Bailey
Scientific Visualization
San Diego Supercomputer Center**

619-534-5142

mjb@sdsc.edu

A Warning !

*Parts of this presentation are
already obsolete !*

(I just can't tell you yet which parts)

A Convention

Buzzword alert !

(By the end, you will be buzzword compliant.)

Where To Start?

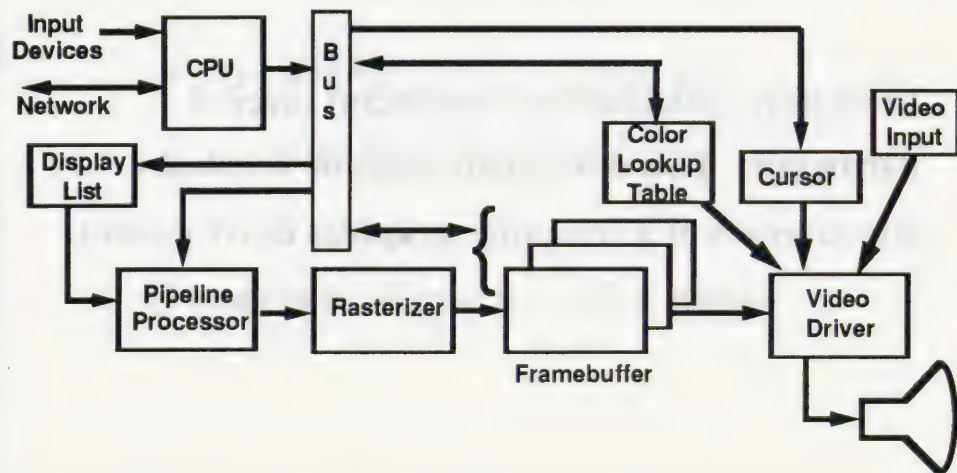
Let's start with the most important piece of hardware. This device can make or break the effectiveness of a computer graphics environment.

...

The Human

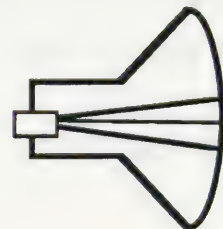
- *Acuity*: 1 arc-minute for those with 20/20 vision
- Required *update rate*: 15+ frames/second
- Required *refresh rate*: 40-70 refreshes/second
- $\approx$ [Red, Green, Blue] receptors in the eye

The Generic Computer Graphics System



Displaying Color on a Computer Graphics Monitor

- *Color guns*
- **Red-green-blue phosphors**
- *Color shadow mask*



Display Resolution

- Pixel resolution (*640x480* to *1280x1024* is common)
- HDTV: 2048x1152 ??
- Screen size (13", 16", 19" are common)
- Human acuity: 1 arc-minute is achieved by viewing a 19" monitor with 1280x1024 resolution from a distance of 40 inches

The Computer Graphics Monitor

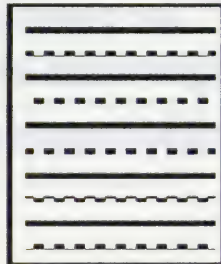


Redrawing the Display

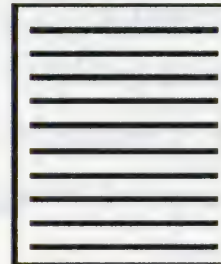
- *Refresh rate* (60-76 Hz is common)
- *Interlacing*

First 1/60 sec ☐

Next 1/60 sec ☐



Interlaced

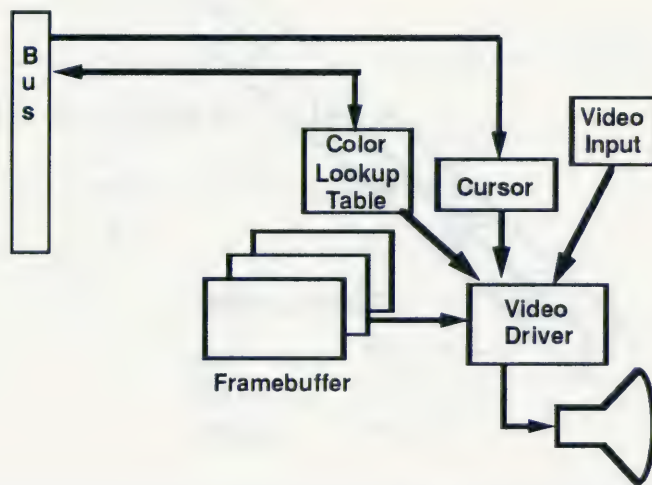


Non-interlaced

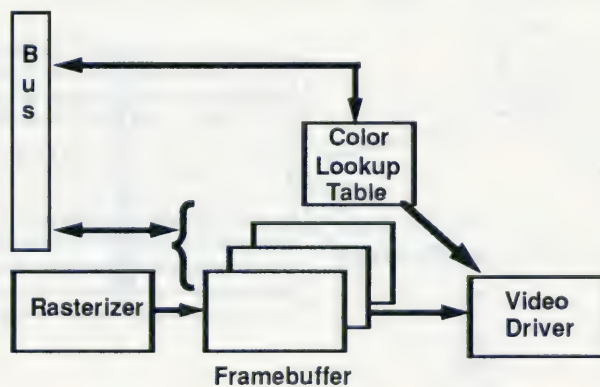
The Video Driver

- N refreshes/second
- Framebuffer
 - *Direct color*
 - *Indirect color with color lookup table (CLT)*
- Cursor
- Video input

The Video Driver

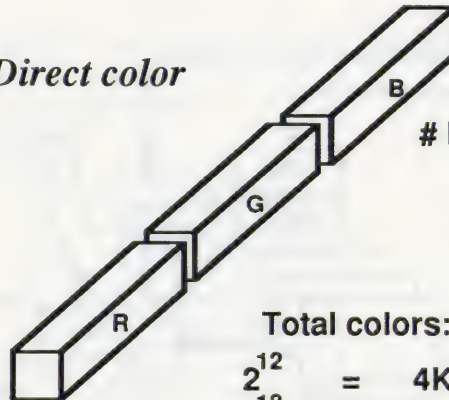


The Framebuffer



The Framebuffer

- *Direct color*



# Bits/color	# Shades
4	16
6	64
8	256

Total colors:

$$\begin{aligned}
 2^{12} &= 4K \\
 2^{18} &= 256K \\
 2^{24} &= 16.7M
 \end{aligned}$$

The Framebuffer

- *Indirect color with color lookup table*



# Bits	# Table Entries
4	16
6	64
8	256
12	4096

0			
1			
2			
3			
4			
5			
6			
7			
N			

The Framebuffer

- *Alpha planes*
 - Typically 8
 - Transparency of each pixel
 - Alpha blending function:

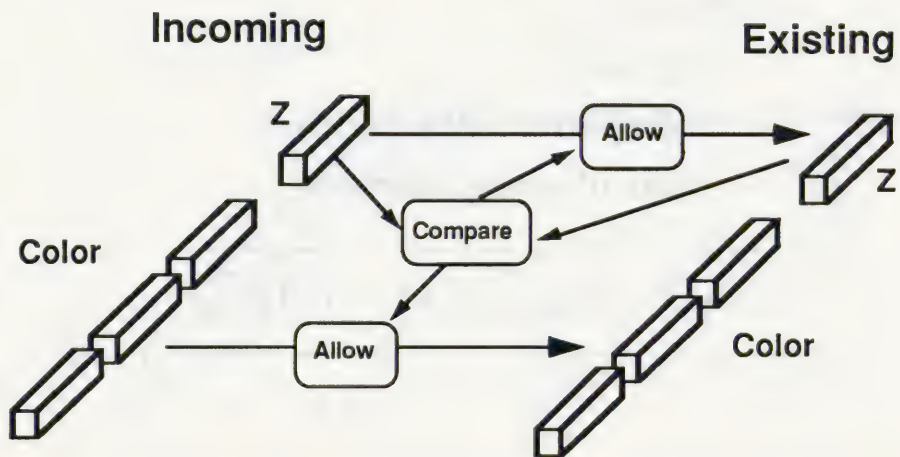
$$Color = \alpha C_1 + (1 - \alpha) C_2$$

$$0.0 \leq \alpha \leq 1.0$$

The Framebuffer

- *Z-buffer*
 - Typically 16, 24, or 32 bits deep
 - Holds pixel depth
 - Used for *hidden surface removal*

Z-Buffer Operation



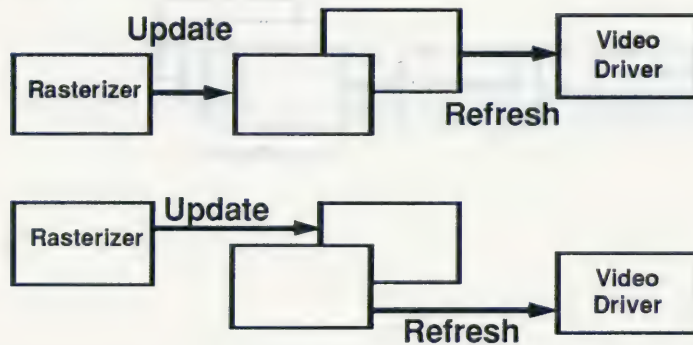
The Framebuffer

- *Overlay planes*
 - Automatically displayed on top of the image in the main framebuffer
 - Good for simple scenes moving on top of a complex background

The Framebuffer

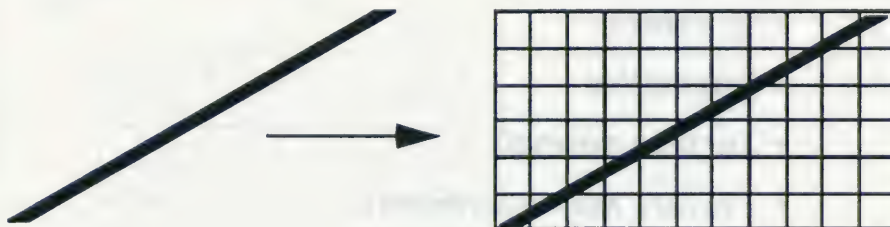
- *Double-buffering*

- Don't let the viewer see any of the scene until the entire scene is rendered

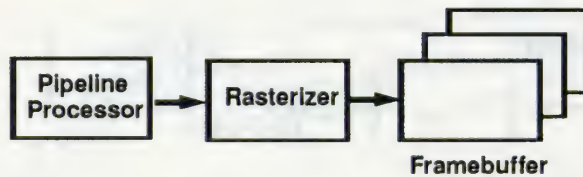


Rasterization

- Turn screen space vertex coordinates into pixels that make up lines and polygons
- A great place for custom VLSI



The Rasterizer



Rasterizers Interpolate:

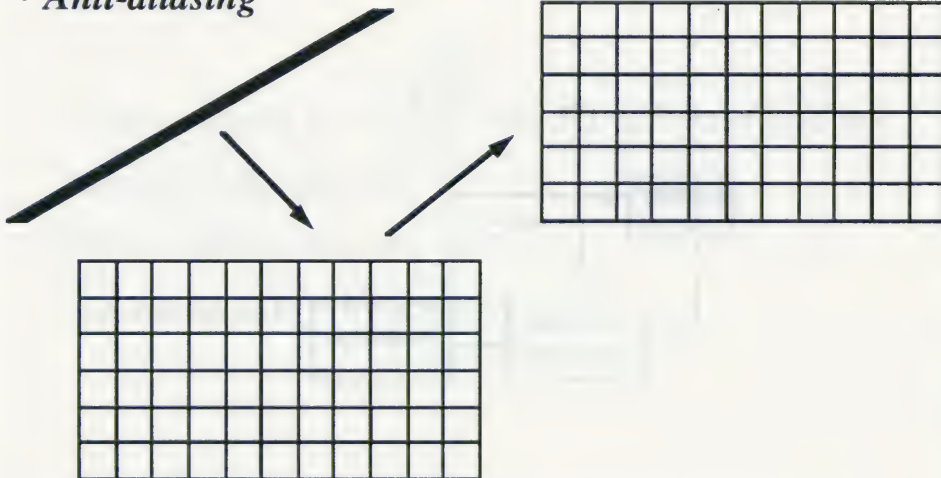
- X and Y
- Red-green-blue values
- Color index values
- *Alpha* values
- Z values
- Intensities
- *Surface normals*
- *Texture map* coordinates

Texture Mapping

- “Stretch” an image onto a piece of geometry
- Very useful for realistic scene generation

Rasterization

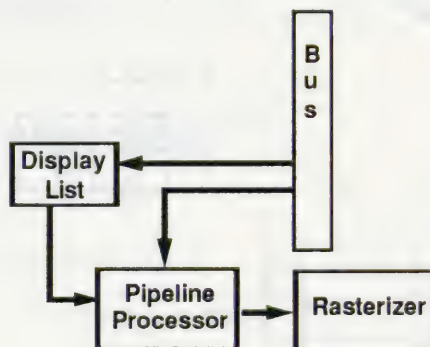
- *Anti-aliasing*



Pipeline Processor

- Coordinates enter in world (application) coordinate space
- Coordinates leave in screen (pixel) coordinate space
- Another great place for custom VLSI

The Pipeline Processor



Pipeline Processor: Transformations

- Used to correctly place objects in the scene

- Translation



- Rotation



- Scaling



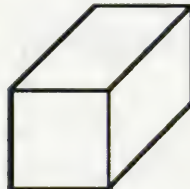
Pipeline Processor: Windowing and Clipping

- Declare which portion of the 3D universe you are interested in viewing
- This is called the *view volume*
- *Clip* away everything else

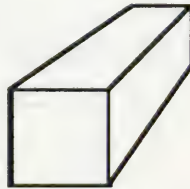
Pipeline Processor: Projection

- Turn 3D coordinates into 2D

- *Parallel projection*



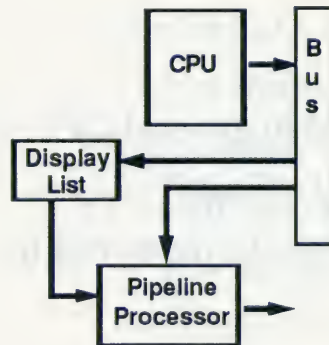
- *Perspective projection*



Display List

- Store often-used pieces of the scene as *structures* (or *objects* or *lists*)
- Advantage:
 - Only have to generate them once
 - Just “call them up” after that

Display List



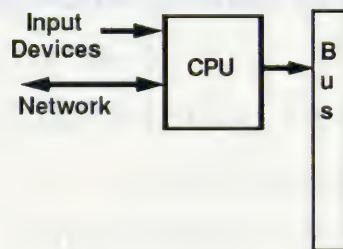
Display List

- Sometimes held in memory on the graphics boards
 - Advantage: very fast to call up
 - Disadvantage: too finite
 - Text fonts often done this way

Display List

- More often held in general CPU memory
 - Advantage: “infinite”
 - Disadvantage: slower to call up

The CPU



Input Devices: General Categories

- Text input
- Choice input
- Value input
- Coordinate input
 - 2D coordinates
 - 3D coordinates

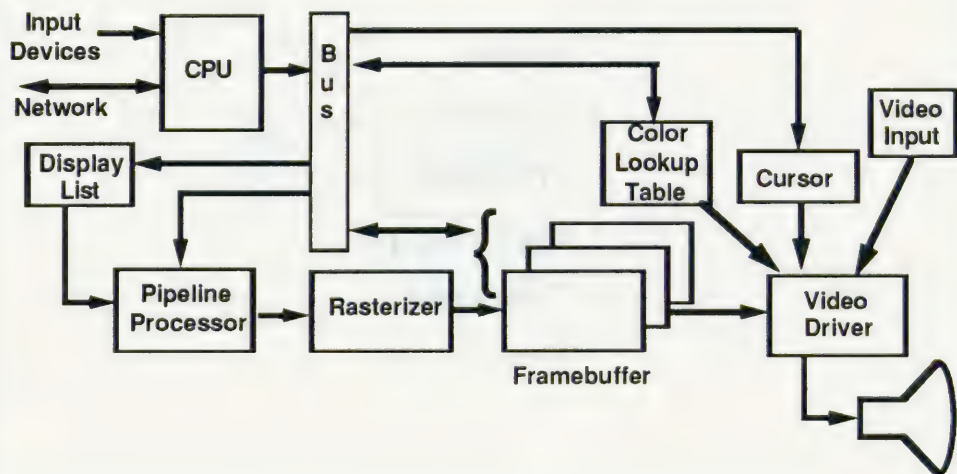
2D Coordinate Input

- Mouse
- Joystick
- Trackball
- Digitizing pen
- Touchpad
- Touchscreen

3D Coordinate Input

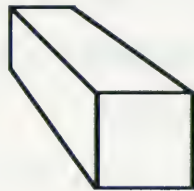
- 3D joystick
- Spaceball
- Wand
- Glove

All Together, Now !

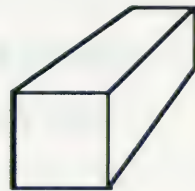


Stereographics

- Simultaneously display both left and right eye views



Left Eye View



Right Eye View

Virtual Reality

Virtual: “In essence, but not in fact.”

VR is a combination of display and interaction technologies that allows a user to suspend disbelief and believe that they are completely existing in and navigating through a *synthetic world*.

Hardcopy

- **Digital film recorders**
- **Analog film recorders**
- **Color paper plotting**

Digital Film Recorders

- **Grayscale monitor**
- **Red-green-blue color wheel**
- **Computer sends:**
 - **The red component of the entire scene**
 - **The green component of the entire scene**
 - **The blue component of the entire scene**
- **Very high resolution: up to 32K x 32K**

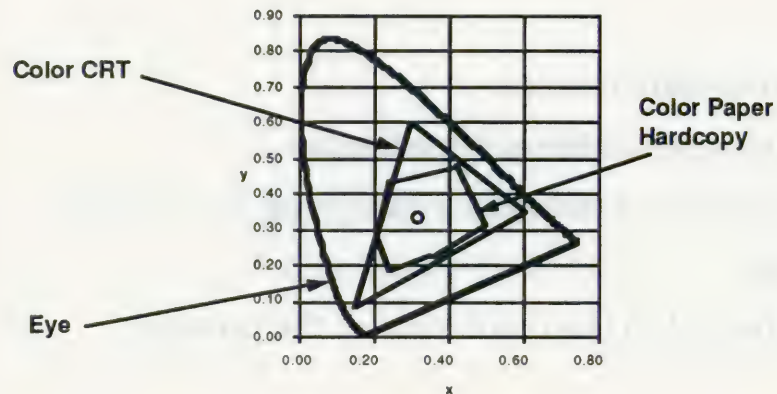
Analog Film Recorders

- **Grayscale monitor**
- **Red-green-blue color wheel**
- **Taps into a monitor's red-green-blue voltage lines**
- **Limited to the resolution of the monitor**

Color Paper Plotting

- *Subtractive color*: cyan, magenta, yellow, black
- **Process must include 4 passes and some way to register the image between passes**
- **Can a color plotter accurately reproduce the colors that I see on my monitor?**

Color Gamuts



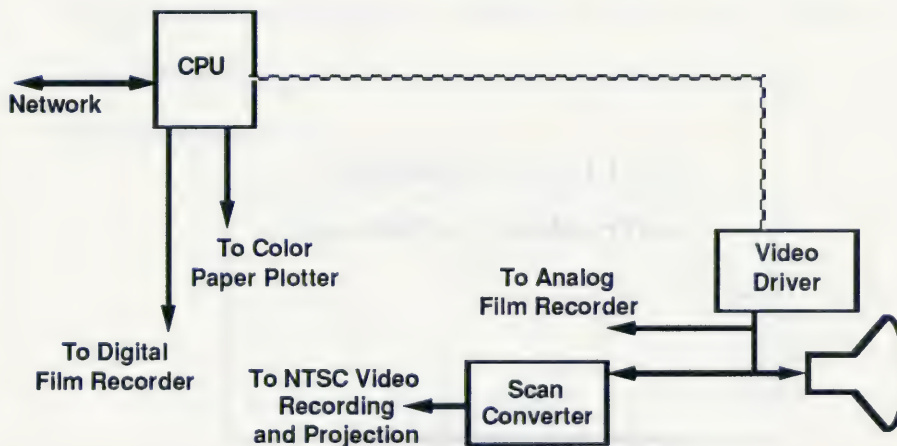
Video: Workstation Monitors versus NTSC

	Workstation	NTSC
Resolution	1280x1024	640x480
Refresh	60-76 Hz	30 Hz
Interlace	Non-interlaced	Interlaced

Video

- *Scan conversion*
- **Frame-by-frame recording**
- **Projection**

Hardcopy Connections



Performance: a Definition

Performance Specification:

**“That level of performance that the device is
guaranteed to never exceed”**



Performance of Computer Graphics Systems

- CPU performance
- Graphics performance

CPU Performance

- MHz
- MIPS
- MFLOPS
- SPECmarks
 - Geometric mean of the scores of various CPU performance tests

$$S_m = \sqrt[n]{S_1 \cdot S_2 \cdot \dots \cdot S_n}$$

Geometric Mean

- Way of producing a composite score that is less influenced by an extra large or an extra small individual score

Scores:	Arithmetic Mean:	Geometric Mean:
2, 3, 4, 5, 10	4.8	4.1
2, 3, 4, 5, 50	12.8	5.7

Graphics Performance

- Primitive level: vectors/second, polygons/second
- Picture level: scene updates/second

To Compare Vector Primitive Specs, You Must Know:

- Vector length
- Vector orientation
- Floating point or integer coordinates?
- *Chained* or *separate* ?

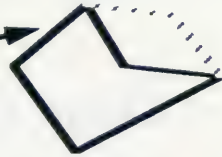


- 2D or 3D?
- Transformed or untransformed?
- Clipped or unclipped?
- Parallel or perspective projection?

To Compare Polygon Primitive Specs, You Must Also Know:



• *Convex* or *Concave* ?



- Number of sides
- With or without z-buffering?
- With or without color interpolation?
- With or without texture mapping?

Standard Graphics Benchmarks

- The *Graphics Performance Characterization (GPC)* committee:
 - Industry-wide
 - Provides standard benchmarks and standard reporting mechanisms
 - OpenGL
 - Picture Level Benchmark
 - X Performance Characterization

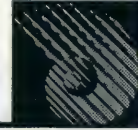
Reading Picture Level Benchmark Results

- A larger number means faster graphics display performance
- *Literal* versus *Optimized*

Recent PLB Results (literal : optimized)

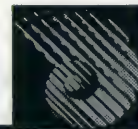
HARDWARE	GRAPHICS LIBRARY	PC BOARD	SYS CHASSIS	SHUTTLE
DEC 3000/800 AXP ZLX-M2	DEC PHIGS	59.1 : 61.8	28.4 : -	81.9 : 82.2
E&S Freedom 3300	ES/TEX	93.4 : 95.0	41.4 : 167.1	131.8 : 139.1
HP 735 CRX24Z	Starbase	52.6 : 57.3	33.3 : 73.6	48.7 : 52.9
IBM RS6000/375 G4xi-24	PEXlib	30.2 : -	29.8 : -	38.5 : -
Kubota 3400 Denali P510	PEXlib	76.2 : -	60.4 : -	62.9 : -
Sun SPARC ZX	XGL	21.1 : 24.6	6.8 : 25.8	18.4 : 22.6

Computer Graphics and Interactive Techniques



- Science
- Education
- Entertainment
- Everyday life

Global Illumination



- Indirectly reflected & transmitted light
- Interchange of light between surfaces
- Visual realism

Ray tracing



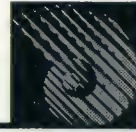
- Calculates paths of light rays
- Good for reflective environment
 - specular reflection
 - refraction through transparent surfaces
- View dependent
- Applications: advertising, CAD/CAE

Radiosity



- Calculates effects of light energy
 - each surface is emitter or reflector
 - all surfaces are broken into patches
 - shooting of light energy from patches
- Good for diffuse lighting environment
- View independent
- Applications: architecture, simulations

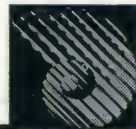
Animation



Animation is not the art of drawings that move, but of movements that are drawn.

-Norman McLaren

Animation



- Key frame
- Interpolation
- Dynamics
- Kinematics

Scientific visualization



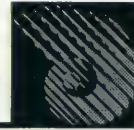
- Information from data
- Insight from images
- Information dissemination

Scientific visualization techniques



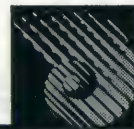
- Image processing
- Volume visualization
- Simulation
- Animation
- Interaction

Image processing



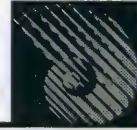
- Modifying visual data
 - usually from external sources
 - photographs, remote sensing, CAT-scans
- Applications: art, medicine

Image processing techniques



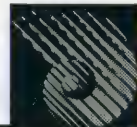
- Image restoration
 - filtering - reduce unwanted features
- Image enhancements
 - pseudo coloring
 - thresholding - create higher contrast
- Applications: medicine, mapping

Scientific visualization examples



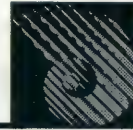
- Animation
- 3D Volumes/Surfaces
- Color
- Design techniques
- Education

Design techniques



The following examples are from a work
in progress by: Colleen Bushell,
Polly Baker, Matthew Arrott, NCSA,
Edward Tufte, Yale University

Virtual environments



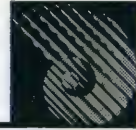
- Emerging technology
- Immersive
 - involving multiple senses
 - participation
- Artificial reality
- Virtual reality

Digital Media



- Multimedia
- Electronic publishing
- Personal technology

Multimedia



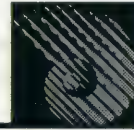
- Integrating graphics, text, sound, video
- Browsing through complex networks
- Advanced communications techniques
- Applications: education, entertainment

Electronic publishing



- Publications on paper
 - new technology for Visual Proceedings
- On-line documents
- CD-ROM proceedings

See for yourself



- Exhibition - premier technology showcase
- Art, design, animation
- Emerging technologies
- Glimpse the future

Courses



- Fundamentals/Overview - Monday
 - More depth
 - Market trends

Slides Used in the Fundamentals Seminar - Software Section

SIGGRAPH '94 Conference, July 24-29, 1994

Wayne E. Carlson

Contact information on all slides is current as of the year the slide was created.

Several additional slides were used in the software presentation, and are not reproduced here because of copyrights or other issues:

- **Introduction**

- the "text" slide was taken from the SIGGRAPH '91 Educators' Slide Set. It is from a tutorial on the technique for performing eye-space transformations.
- the "photo-realistic" image was made by Prof. Virginia Weinhold of ACCAD at The Ohio State University. It was used in her research as to the use of radiosity to investigate interior lighting perceptions.

- **Anti-aliasing**

- the "NO JAGGIES" slide was made by Dicomed for SIGGRAPH '81.

- **Techniques of modeling**

- the slides explaining extrusion, surfaces of revolution, and lofting were taken from a 1984 Master of Arts thesis by Judy Sachter at ACCAD at The Ohio State University. This thesis is entitled "The Basic Concepts of Three-Dimensional Computer Graphics for Artists".
- the solids modeling slide was made by Ferdi Scheepers as part of a proof of concept for his Ph.D. work in the Department of Computer and Information Science at The Ohio State University.

- **Scene Composition**

- the slide depicting scene composition was from the *Shutterbug* series made by Williams, Siegle and Mantle of Pixar, and included in the SIGGRAPH '91 Educators' Slide Set. They are also reproduced in the text *Computer Graphics, Principles and Practice*, by Foley, van DAM, Feiner and Hughes (Addison-Wesley, 1990).

- **Lighting**

- the 'ball and stick' models used to exhibit diffuse and specular shading were provided by Frank Crow.

- **Projection**

- the 4 slides showing the various approaches to projection (parallel, orthographic, perspective, and one-point) were made by

Fuller and Prusinkiewicz at the University of Regina and are included in the SIGGRAPH '91 Educators' Slide Set.

- **Hidden Line**

- the 2 slides showing hidden line elimination are from the *Shutterbug* series from Pixar.

- **Shading**

- the 3 slides showing faceted, Gouraud, and Phong shading are from the *Shutterbug* series from Pixar.

- the wine glasses showing transparency were made by Michael Collery of Pacific Data Images.

- the 2D texture mapping slides are from the *Shutterbug* series.

- the 3D textures were done by David Ebert of the Computer Science Department at The Ohio State University.

- the 'bump-mapping' slides are from the Jet Propulsion Laboratory.

- the 'reflection mapping' slides are from the *Shutterbug* series from Pixar.

Slides and Videos Used in Fundamentals Seminar - Applications Section

SIGGRAPH '94 Conference, July 24-29, 1994

Judith R. Brown

Contact information on all slides is current as of the year the slide was created.

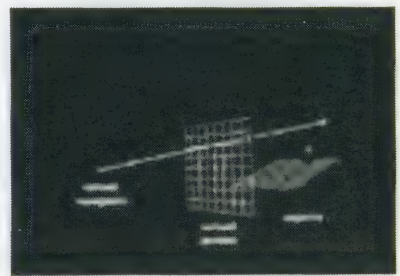
Ray tracing slides, slides 2-27 of the SIGGRAPH '91 Educators' Slide Set

These slides were produced by Michael Sweeney with the help of David Forsey, David Martindale, and Robert Krieger, University of Waterloo. Copyright 1984, University of Waterloo. These slides are from the video, "Ray Tracing: A Silent Movie and Some Slides," SIGGRAPH Video Review #14, 1985. They are a good introduction to the fundamental principles of ray tracing, and also have historical value. The text of the slides is as follows:

Ray Tracing: Some Slides



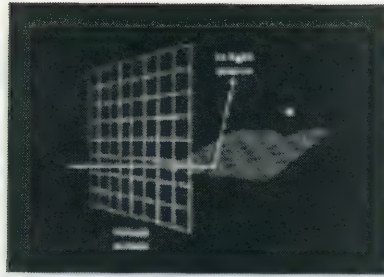
In Ray Tracing, a virtual screen and a virtual viewpoint are defined in the same coordinate system as the objects to be rendered.



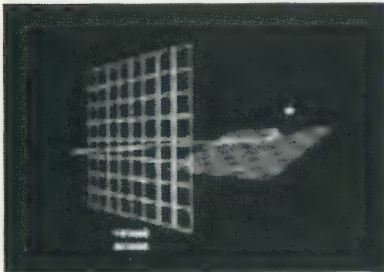
A line ("ray") is projected from the viewpoint through every point in this screen, and on into the object space.



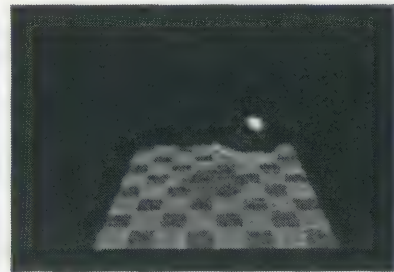
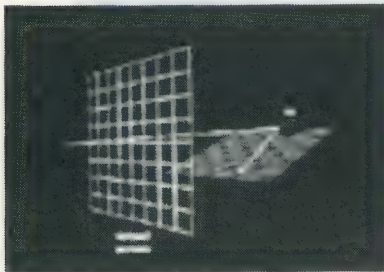
The ray is tested for intersection against every object in the scene. If no object is hit, you see background. Otherwise, you see the closest object to the viewpoint.



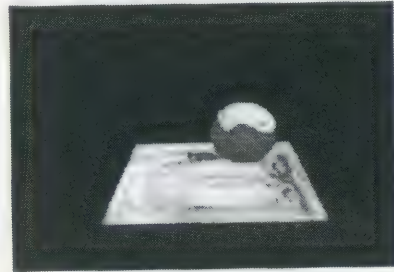
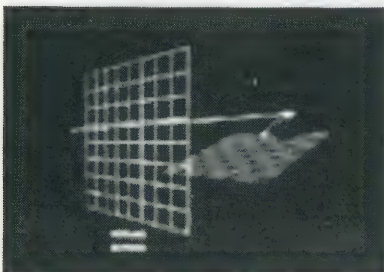
If an object is hit, a ray is projected from the intersection point towards the animated light source.



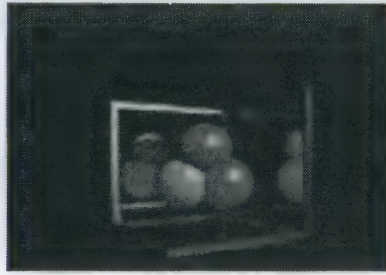
If this ray hits another object on it's way, the intersection point is in the shadow.



If the object happens to be reflective, a "secondary ray" is projected from the intersection point (angle of incidence equals angle of reflection).



If the object is transparent, the secondary ray is projected in the direction indicated by the index of refraction.

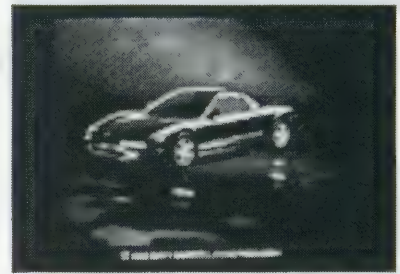


Of course, if the secondary ray hits something reflective, tertiary rays are generated. And so on, and so on, and so on.....

Ray tracing examples



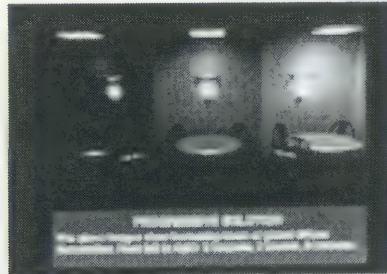
Glass night, Satoshi Naito, SIGGRAPH '91 Technical Slide Set, #66. This is a ray traced solid glass model. The knight is modeled by 840 triangles. It was created on an Epson personal computer PC-286 VS using proprietary ray tracing software. Contact: Satoshi Naito, Kyodo News Service Computer Section, 2-2-5, Toranomom, Minato-ku, Tokyo 105, Japan, 03 3584 4111.



Studio NSX, Gary Mundell, Andrew Pierce, SIGGRAPH '92 Technical Slide Set, #39. Raytraced in parallel on a 32 processor machine, this image displays the use of area light sources with realistic water puddles generated through fractal procedures. Alias Studio software and IBM PVS 32 processor parallel computer were used. Contact: Gary Mundell, Alias Research Inc., 110 Richmond St. E., Toronto, Ontario M5C-1P1, Canada, +1 416 362 9181.

Examining Radiosity

The following four examples are taken from a set of twenty-six slides, "Examining Radiosity," that is part of the SIGGRAPH '93 Educators' Slide Set. The entire set explains the radiosity method for computer image generation and how the basic algorithm has been extended. This slide set was created by Wayne Carlson, Peter Carswell, Yina Chang, Erica Galvao, Carol Gigliotti, Barb Helfer, James Kent, Stephen May, Kevin Simon, Stephen Spencer, Virginia Weinhold, and Greg Ward, all from The Ohio State University Advanced Computing Center for the Arts and Design and the Ohio Supercomputer Center.



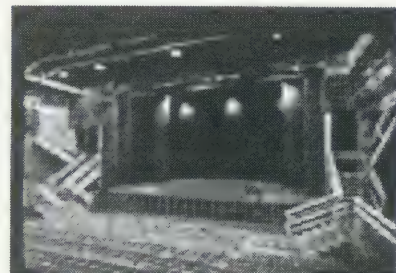
Progressive Radiosity Examples, slide #65, modeled by German Bauer, Kevin Simon, and Virginia Weinhold, using in-house modeling and animation software and rendered with the RADIANCE global illumination package, designed by Greg Ward. Copyright 1992, ACCAD, The Ohio State University.

This slide illustrates the iterative nature of the progressive method. The composite image shows that as the number of iterations increase, the accuracy of the intensity solution (and, hence, the resulting image) also increases. Of particular interest is the contribution of the color of the walls of the room to the overall color of the room in the right-most section of the composite image.

This image was created by calculating three separate images, each halted at a different stage of rendering, and composited together afterwards.



Theatre, slide #75, shows a model of a proposed theater near Candlestick Park in San Francisco, and contains 1,061,543 surface elements.



Theatre With Polygonal Mesh, slide #76, is the same model of the theater in the previous slide, with the surface element mesh visible.

The **Theatre** images are courtesy of Dan Baum. The radiosity algorithms and software used in the creation of these images are described in "Making Radiosity Usable: Automatic Preprocessing and Meshing Techniques for the Generation of Accurate Radiosity Solutions," by Daniel R. Baum, Steve Mann, Kevin P. Smith and James W. Wingett, *SIGGRAPH '91 Proceedings*.

The hardware used to create these images was a Silicon Graphics 4D-310 GTX. The Candlestick Theater architect is Mark Mack Architects. Database modeling is by Charles Ehrlich, Department of Architecture, University of California at Berkeley.



Le Corbusier's Chapel at Ronchamp, slide # 78, courtesy of Eric Haines, 3D/EYE Inc. It was modeled by Keith Howie and Paul Boudreau, and rendered by Eric Haines. Copyright 1991, The Hewlett-Packard Company.

This view of Le Courbusier's Chapel at Ronchamp was created using 4,000 steps of progressive radiosity. The stained glass windows were simulated using 113 area light sources. The radiosity solution was computed using Hewlett-Packard's licensable ARTCore Radiosity and Ray Tracing library running on an HP Model 835 TurboSRX workstation. The sunbeams were rendered using specially written ray tracing software run as a view-dependent post-process to the radiosity solution.

Slides illustrating a combination of ray tracing and radiosity



Glossy Floor, after Vermeer, John R. Wallace, SIGGRAPH '87 Technical Slide Set, # 68. Illumination for this slide was calculated using a hybrid of radiosity and distributed ray tracing, using a VAX 8700 and displaying at 1280 x 1024. Contact: John R. Wallace, Cornell University Prog. of Computer Graphics, 120 Rand Hall, Cornell University, Ithaca, NY 14853-5501, +1 607 255 6715.



Mona's Suburban Cafe, Peter Segal, SIGGRAPH '91 Technical Slide Set, #58. Radiosity solution is applied to reflect sunlight off the back of the menu onto the cups and tray. The scene is then ray traced to add highlights, reflections and transparency. Total time, including up to nine antialiasing samples for the 1024x1024 image, is under 20 minutes. The image was created on an AT&T Pixel Machine #964 and Solbourne workstation using RAYlib integrated ray tracing and radiosity library. Contact: Peter Segal, AT&T Pixel Machines Room 2M333, Crawfords Corner Road, Holmdel, NJ 07703, +1 908 949 1244.

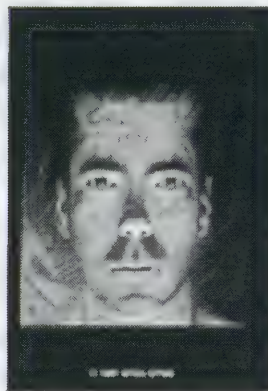
Image processing slides



Interactive Image, Electronic Visualization Lab, University of Illinois, Chicago. One of the Interactive Image games teaches about digital image processing.



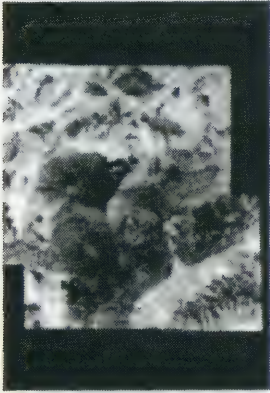
Out of Body, Jack Cliggett, SIGGRAPH '91 Art and Design Show Slide Set, #18. Photographic print, 8x8 in. Contact: Jack Cliggett, Drexel University, College of Design Arts-Graphic Design, 33 & Market Streets, Philadelphia, PA 19104, +1 215 623 1606.



Self Portrait, Erol Otus, SIGGRAPH '91 Art and Design Show Slide Set, #23. Ink jet printout, 36x30 in. Contact: Erol Otus, 509 Bonnie, El Cerrito, CA 94530, +1 415 491 1000.

Slides illustrating image processing techniques that were shown were courtesy of Gloria Brown-Simmons. These included images of a toy robot illustrating histograms, thresholding, and filters.

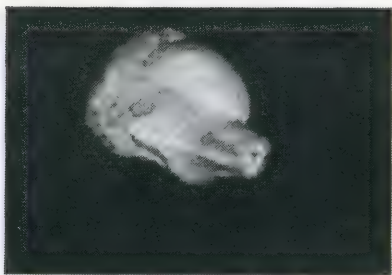
Scientific visualization slides



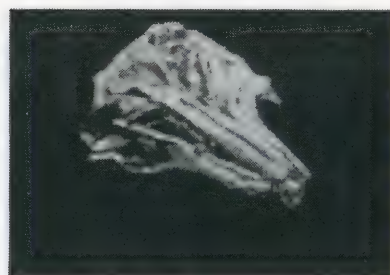
Landsat Mosaic, courtesy of Gloria Brown-Simmons. Image processing techniques and colors were chosen which emphasize compositional variation in the rocks. Image made by Bob Grippen and Gloria Brown-Simmons, using a VAX 3600 and VICAR software, Jet Propulsion Labs, 1988.



Turtle Mountains Crustal Block, Gloria Brown-Simmons, SIGGRAPH '91 Technical Slide Set, #50. This image shows processed LANDSAT and seismic data rendered with a terrain model. Surface colors and shapes assist researchers in locating high angle faults. The seismic data reveals the complex series of low-angle faults. The image was created on a SGI 3030, Alliant FX8 and a VAX 3650 using VICAR image processing system and Wavefront. Contact: Gloria Brown-Simmons, JPL/Caltech MS 168-514, 4800 Oakgrove Drive, Pasadena, CA 91109, +1 818 354 4370.



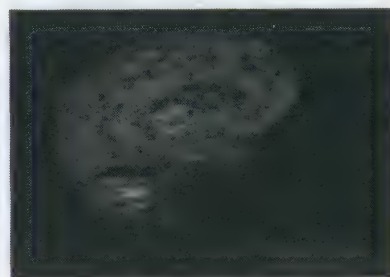
Dolphin Head, by T. Todd Elvins, San Diego Supercomputer Center. Data is from Ted Cranford, UC Santa Cruz, who is studying focused echo location capabilities in marine animals. Image is from 230 slices of CT scan data, using the Ray-casting algorithm in "voxvu" software on a Sun Microsystems workstation.



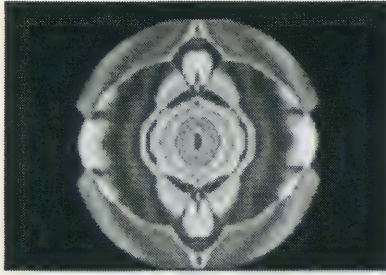
Dolphin Skull. Visualization by T. Todd Elvins, San Diego Supercomputer Center, with his software, "parv." The data, 230 slices of CT scan data of a dolphin head, was acquired by Ted Cranford, University of California, Santa Cruz.



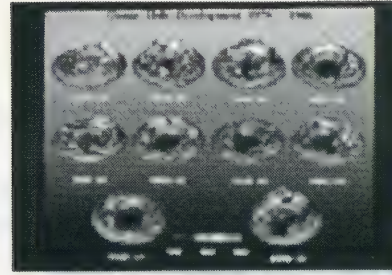
Dust Storm. One frame from an animation of a simulated dust storm over the Pacific Basin by Greg Carmichael, Veerabhadra Rao Kotamarthi, and Young Sunwoo, University of Iowa. Visualization by James Durcheinwald and John Knaack on a DECStation 5000.



Human Brain. Model of the human brain. Visualization done by Holliday Horton, San Diego Supercomputing Center, using Wavefront's renderer. The data comes from UCSD's Livingston Laboratory.



Neutron Star Collision, National center for Supercomputing Appli-
Scientist: Charles Ross
Evans III. Artist: Donna Cox.



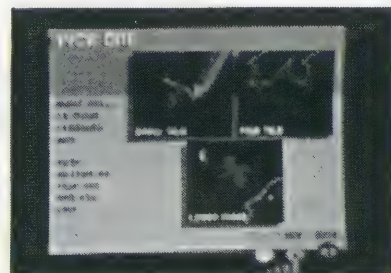
Ozone Hole Development,
SIGGRAPH '92 Industry /
Applications Slide Set, #45.
This image depicts the development
of the ozone hole over the
southern hemisphere from 1979-
1988, data from TOMS data, NASA
Langley. Mark Bolstad, John Spence,
Bob Hangebrouck, Theresa-Marie
Rhyne, Unisys Corporation, US EPA
Visualization Center, EPA Mail Drop
34C, Research Triangle Park, NC
27709.

Virtual environments

Slides illustrating virtual environments that were shown were courtesy of Myron Krueger, Artificial Reality Corporation, and Henry Fuchs, University of North Carolina, Chapel Hill.

Multimedia slides

Interactive image - two slides.

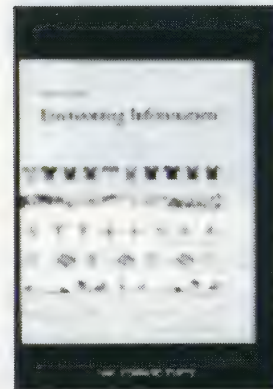


These workstations were developed to teach computer graphics to children. They were developed at Electronic Visualization Lab, University of Illinois, Chicago, partially funded by SIGGRAPH. They are on permanent exhibit at the Computer Museum in Chicago.

Electronic publishing slides



Adobe Systems Incorporated 1989 Annual Report, Adobe Systems marketing Communications, SIGGRAPH '91 Art and Design Show Slide Set, #54. Annual report, 11x8.5 in. Contact: Alice Peterson, Adobe Systems Incorporated, 1585 Charleston Road, Mt. View, CA 94043, +1 415 961 4400.



Envisioning Information, Graphics Press, SIGGRAPH '91 Art and Design Show Slide Set, #57. Book, 10.75x8.875 in. Contact: Edward Tufte, Graphics Press, Post Office Box 430, Cheshire, CT 06410, +1 203 272 9187.

Videotapes

The House That Radiosity Built: An Introduction to the Radiosity Method SIGGRAPH Video Review Issue 74, #29, 1991.

Summary: An introductory tutorial on the radiosity method. State-of-the art environment preprocessing and radiosity solution algorithms were used to generate the video.

Produced by: Daniel R. Baum and Kevin P. Smith, Silicon Graphics.

Hardware: SGI IRIS 4D 340 VGX

Software: In-house radiosity and viewing software

Contact: Daniel Baum, Silicon Graphics, 2011 N. Shoreline Blvd., M57U-550, Mountain View, CA 94039-7311, USA, +1 415 962 3671, +1 415 965 7651 (fax).

Luxo, Jr.

Pixar, directed by J. Lasseter and W. Reeves, 1986.

Luxo, Jr., a milestone in computer animation and the first three-dimensional computer-animated film to be nominated for an Academy Award, is a brief vignette starring a father-son team of Luxo lamps. The lamps are playing with a rubber ball when **Luxo, Jr.** accidentally bursts his toy. The film is remarkable for its ability to endow inanimate objects with distinct human personalities and to capture the emotional intensity of a father-son relationship. The characters communicate compassion and remorse with merely the wave of a lamp cord and the dip of a metallic head. In addition, **Luxo, Jr.** represents several technical achievements by Pixar in the field of computer animation, most notably self-shadowing, which allows an object accurately to project shadows on itself. **Luxo, Jr.** has received awards from over 20 international film festivals and competitions.

Contact: Direct Cinema Limited, P.O. Box 69799, Los Angeles, CA 90069, USA, +1 213 652 8000.

Random Dot Motion

SIGGRAPH Video Review Issue 42, #2, 1989, copyright 1989, Daniel J. Sandin.

Summary: This demonstration shows the importance of animation in discovering patterns in data that changes over time.

Credits: Daniel J. Sandin and Thomas A. DeFanti.

Hardware: AT&T 386 with Truevision VISTA.

Software: RT/1.

Contact: Daniel J. Sandin, University of Illinois at Chicago, Electronic Visualization Laboratory, Box 4348, M/C 154, Chicago, IL 60680, +1 312 996 3002.

Mathematics! Similarity

SIGGRAPH Video Review Issue 62, #21, 1990. Excerpt from a module of the Mathematics! project, a series of videotapes to aid in teaching high school mathematics.

Produced by: Jim Blinn

Hardware: Hewlett-Packard Vectra 25, 386-based personal computers

Software: Home Grown

Contact: Joe Corrigan, CalTech 1-70, Pasadena, CA 91125, USA, +1 818 356 3758

NASA Ames Virtual Windtunnel

SIGGRAPH Video Review Issue 71, #21, 1991. Computational fluid dynamics techniques are used to simulate a virtual environment for the visualization of 3D fluid flow structures.

Produced by: Steve Bryson and Creon Levit

Hardware: Boom - Fake Space Labs, Glove - VPL Research, Rendering - Silicon Graphics; Software: Proprietary

Contact: Steve Bryson, MSTO45-1, NASA Ames Research Center, Moffett Field, CA 94035, USA tel. +1 415 604 4524, fax. +1 415 604 3957.

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Issues are available in NTSC VHS or U-Matic, and some recent issues are also available in PAL.

To order copies of Luxo, Jr. or other Pixar videos:

Direct Cinema Limited

P.O. Box 69799

Los Angeles, CA 90069

+1 213 652 8000

To order copies of the Mathematics! videos:

Caltech Bookstore, 1-51

Pasadena, CA 91125

+1 818 356 6161

For more information on Mathematics!, contact Project Mathematics!,
Caltech 1-70, Pasadena, CA 91125.

Selected Bibliography

The following list contains a selection of textbooks or handbooks that give an introduction to computer graphics or introductory detail to more complex areas in the discipline. An extensive bibliography of SIGGRAPH conference technical contributions can be found in the SIGGRAPH '94 Proceedings. SIGGRAPH also maintains the SIGGRAPH Online Bibliography at the siggraph.org site. A technical discussion of this service can be found in the January 1993 SIGGRAPH Quarterly Newsletter. This service is also available on the World Wide Web. The Course Notes for the Fundamentals and Overview of Computer Graphics course also contains an extensive bibliography, as well as a list of graphics related resources.

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- Communications of the ACM
- Computer Graphics
- Quarterly Newsletter of ACM SIGGRAPH
 - Proceedings of the SIGGRAPH Annual Conference
- Computers and Graphics
- Computer Graphics World
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